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DESIGN AND EXPERIMENTAL ANALYSIS OF HELICAL SUSPENSION SPRING WITH DIFFERENT MATERIALS

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ABSTRACT

Automobile suspension plays an important role in passenger comfort and stability of the vehicle. So far now, many materials have been evaluated for manufacturing of helical suspension springs as per requirement. The objective of this work is a comparative study and analysis of suspension helical coil spring with two different materials (chrome silicon and hard drawn carbon steel) and perform experimental and static analysis using finite element analysis to determine the optimum material to reduce the stress and deflection. Suspension model is created in ProE CREO 2.0 and the model is structurally analyzed using ANSYS 15.0. Helical suspension springs of two materials are prepared and experimental tests are performed for analysis of physical characteristics for the two materials. The results and comparative study show the optimum material that can be selected as a spring material for efficient function and long life.

KEYWORDS: Helical Suspension Springs, Finite Element Analysis, Static Analysis & Experimental Analysis

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Original Article

INTRODUCTION

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. It is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication. Some non-ferrous metals are also used, including phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for spring carrying electrical current (because of its low electrical resistance). When a spring is compressed or stretched, the force it exerts is proportional to its change in length. Helical springs are simple forms of springs, commonly used for the suspension system in wheeled vehicles [1]. The vehicle suspension system is made out of springs that have a basic role in power transfer, vehicle motion and driving. Therefore, springs, performance optimization plays important role in improvement of car's dynamic. The automobile industry tends to improve the comfort of the user and reach an appropriate balance of comfort riding qualities and economy [6]. The helical springs are said to be closely coiled when the spring wire is coiled so close that the plane containing each turn is nearly at right angles to the axis of the helix and the wire is subjected to torsion. In other words, in a closely coiled helical spring, the helix angle is very small; it is usually less than 10 degrees. The major stresses produced in helical springs are shear stresses due to twisting. The load applied is parallel to or along the axis of the spring. In open coiled helical

springs, the spring wire is coiled in such a way that there is a gap between the two consecutive turns, as a result of which the helix angle is large. Typical applications are car and bike suspension and matters spring. Compression springs typically have their ends end and allowing for easy mounting. A coil is made from a single length of wire which is heated and wound on a former to produce the required shape. The load carrying ability of the spring depends on the diameter of the wire, outer diameter, pitch, strength of the material and few more design parameters.

MATERIAL PROPERTIES

Table 1: Material Properties: Chrome Silicon Spring Steel

Modulus of Rigidity	Young's Modulus	Density	Poisson's Ratio	Ultimate Tensile Strength
79300 MPa	207000 MPa	7350 Kg/m^3	0.27	1620-2070 MPa

Table 2: Material Properties: Hard Drawn Carbon Spring Steel

Modulus of Rigidity	Young's Modulus	Density	Poisson's Ratio	Ultimate Tensile Strength
71420 MPa	207000 MPa	7850 Kg/m^3	0.35	1014-1950 MPa

DESIGN SPECIFICATIONS OF HELICAL SPRING

- **Wire Diameter (d):** 12 mm
- **Mean Diameter of Spring (D):** 75 mm
- **Outer Diameter of Spring (d_o):** 87 mm
- **Free Length of Spring(l):** 210 mm
- **No of Active Coils (i):** 6
- **Pitch (p):** 30 mm
- **Load on Spring (F):** 2500 N

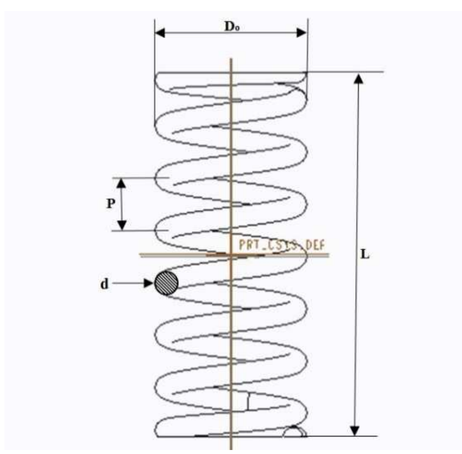

Figure 1: Design of Helical Spring

THEORETICAL ANALYSIS

- Spring Index

$$\mathbf{c = (D/d)} \tag{1}$$

- Stress Factor

$$\mathbf{k = (4c\text{-}1) / (4c\text{-}4)} \tag{2}$$

- Maximum Shear Stress

$$\boldsymbol{\tau} = \mathbf{(8FDk) / (\Pi d^3)} \tag{3}$$

- Maximum Deflection

$$\gamma_{max} = \mathbf{(8FD^3 i) / (d^4 G)} \tag{4}$$

- Stiffness Of Spring

$$\mathbf{K = (F / \gamma_{max})} \tag{5}$$

Table 3: Analytical Results for Chrome Silicon Steel Spring and Hard Drawn Carbon Steel Spring

Parameters	Chrome Silicon	Hard Drawn Carbon Steel
Spring index (c)	6.25	6.25
Stress factor (K)	1.24	1.24
Max shear stress (τ_{max})	342.5 Mpa	342.5 Mpa
Max deflection (γ_{max})	28.5 mm	32.5 mm
Spring stiffness (k)	90.90 N/mm	76.92 N/mm

STATIC ANALYSIS THROUGH FINITE ELEMENT METHOD

Finite element method is a numerical procedure for obtaining approximate solutions for many problems encountered in engineering analysis. In FEM complex region defining a continuum is discredited into simple geometric shapes called elements, the properties and relations are assumed over these elements and expressed mathematically in terms of unknown values at specific points in the elements called nodes. When the effects of loads and boundary conditions are considered, a set of linear or non-linear algebraic equations is usually obtained. The solution of these equations gives the approximate behavior of the component or the machine. The component has an infinite number of degrees of freedom while the discredited model has a finite number of degrees of freedom; this is the origin of the name finite element method [4]. The static analysis calculates the effects of steady loading conditions on the structure, while ignoring inertia and damping effects that are caused by time-varying loads. Static analysis can, however, includes steady inertia load such as gravity and rotational velocity and time varying loads that can be approximated as static equivalent loads. Static analysis is used to determine the displacements, stresses, strains and pressures in structures or components caused by loads that do not include significant inertia and damping effects. Steady loading and structure response are assumed to vary slowly with respect to time.

The helical spring is modelled in CREO 2.0 according to the design specifications, material properties are applied and the model is imported to ANSYS 15.0 to perform static analysis and meshing is applied.

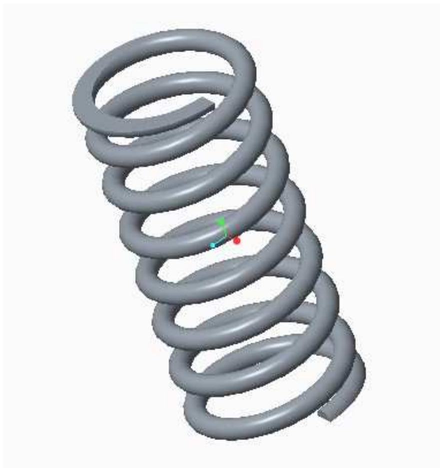

Figure 2: PRO E CREO Spring Model

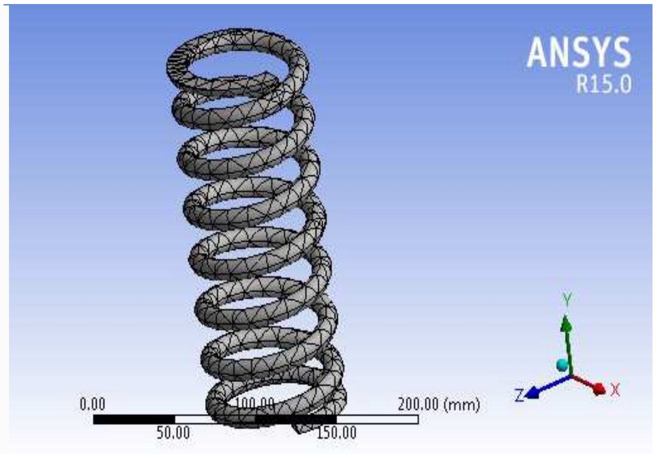

Figure 3: Model Mesh in ANSYS 15.0

Boundary Conditions

To perform static analysis, few constraints apply to the component as the component contains several degrees of freedom; restriction of few of these degrees of freedom is achieved by applying boundary conditions. In static analysis the helical spring is provided with zero displacement constraint at one end and Load of 2500 N is applied at the other end for both the chrome silicon steel and hard drawn carbon steel materials. On solving this process the maximum shear stress induced in the spring and maximum deflection offered by the spring for the applied load for both materials are obtained which has to be within the safe design limit to be considered as for practical application. The analysis result of maximum shear stress and maximum deflection are shown below.

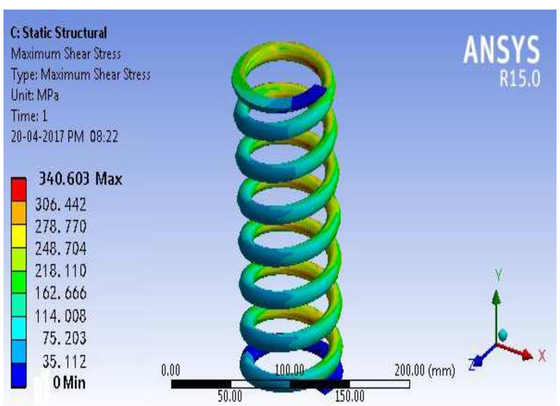

Figure 4: Maximum Shear Stress for Chrome Silicon Spring

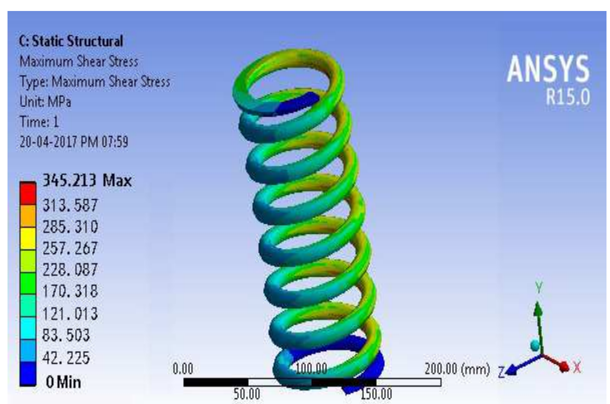

Figure 5: Maximum Shear Stress for Hard Drawn Spring

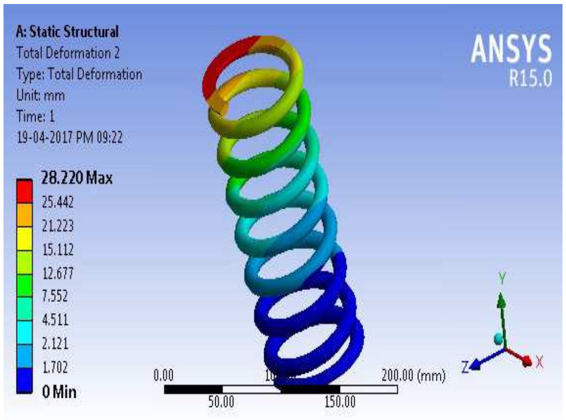

Figure 6: Maximum Deflection for Chrome

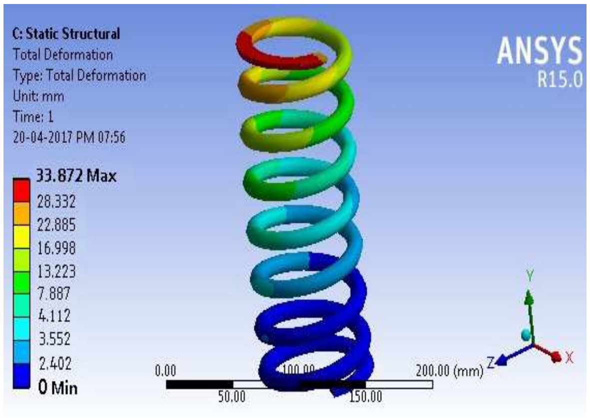

Figure 7: Maximum Deflection for Hard Silicon Spring Drawn Spring

By the static analysis results it is observed that max shear stress for chrome silicon steel is 340.603 Mpa and of hard drawn carbon steel is 345.213 Mpa. Max deflection in chrome silicon steel spring is 28.220 mm and for hard drawn carbon steel is 33.872 mm.

EXPERIMENTAL ANALYSIS

Fabrication of helical suspension spring is carried out in sequential process as shown below.

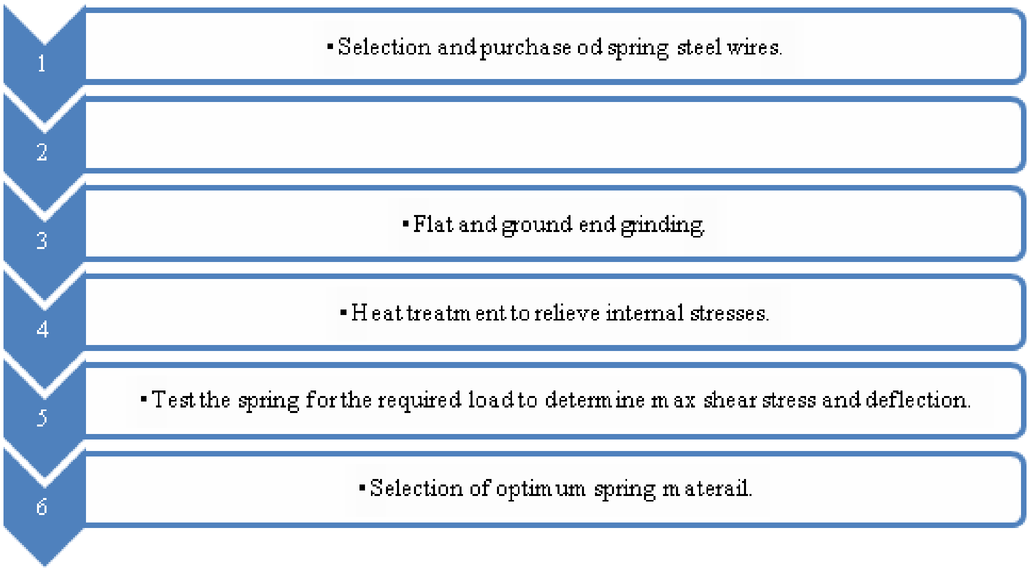

Chart 1: Process of Spring Manufacturing

Coiling of Wires to Spring Form

Figure 8: Coiling of Spring Wire in Coiling Machine

Spring steel wires are commonly available in wire forms, these wires are then coiled cold forming or hot rolling. Both chrome silicon and hard drawn carbon steel wires are called according to the design specifications using coiling machine with the help of Mandal used for inner diameter support as shown in the figure above.

Squared and Ground End Grinding

Figure 9: Flat and Squared Grinding

Figure 10: Hard Drawn Carbon Steel Spring

Figure 11: Chrome Silicon Steel Spring

Coiled springs then grind at the ends using abrasive grinding machine to provide ground and squared ends so that the surface is horizontal and flat for easy loading, however the ground ends are not considered for load resistance and are called inactive coils.

Heat Treatment Process

Figure 12: Heat Treatment of springs

Heat treatment is provided in order to remove any internal stresses or residual stresses in the spring. Springs are kept in the heat treatment device and are heated to 350ºc for about 30 minutes, so that the internal stresses are relieved and the molecular structure of the party is reoriented to resist the loads.

Load Test

Figure 13: Spring Load Test Rig

The springs are subjected to loads up to 2500N to determine the maximum deflection of the spring.

Table 4: Deflection in Springs per Unit Load

Load in Newton	Chrome Silicon Spring Deflection in Mm	Hard Drawn Carbon Spring Deflection in Mm
500	3	7.2
1000	8.2	12.8
1500	15	19.7
2000	22.2	27
2500	29	34

CONCLUSIONS

Table 5: Comparison of Results

Material Type	Load In Newton	Theoretical Results	Ansys Results	Experimental Results
Chrome silicon spring	2500	28.5	28.220	29
Hard drawn carbon spring	2500	32.5	33.887	34

It is proved theoretically, through ANSYS and experimentally that the spring in which maximum shear stress is induced i.e. 345.213 Mpa ANSYS result and 342.5 Mpa theoretically for provided load is hard drawn carbon spring than in chrome silicon spring where maximum shear stress induced in 340.603 Mpa ANSYS result and 342.5 Mpa theoretically and deflection induced in chrome silicon spring is very much less than deflection induced in hard drawn carbon spring as shown in above table, the weight and density of chrome silicon spring is lesser than hard drawn carbon spring. So Chrome silicon spring steel is the optimum suitable material with low weight and high stiffness for helical spring application like mono shock suspensions in bikes and many more.

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